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ANNUAL REPORT

OF THE

DIRECTOR

BUREAU OF STANDARDS

TO THE

SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1913



WASHINGTON
GOVERNMENT PRINTING OFFICE
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DIRECTOR, BUREAU OF STANDARDS.

DEPARTMENT OF COMMERCE,
BUREAU OF STANDARDS,
Washington, July 1, 1913.

SIR: There is submitted herewith a report of the work of the Bureau of Standards for the fiscal year ended June 30, 1913.

The report of the activities of the Bureau during the year necessarily gives but the briefest summary of its work. In no year of its history has there been as full cooperation of all divisions of the Bureau in testing and research. This cooperation has minimized the somewhat narrowing effects of a rigid division system. Each problem when studied in a broad scientific spirit leads into every specialty, so that the fullest cooperation of the entire Bureau is essential to its success. The gratifying results of such cooperation are particularly notable in the development of standards for gas, in the researches upon metals, and the methods of testing the properties of materials, in the study of electrolysis experimentally and in the field, in the structural materials investigation, and in many other cases where success depends upon many specialties.

In no case is such cooperation more striking than in the gradual development of the public-service commission work of the Bureau. This is an outgrowth of the weights and measures activity of the Bureau, of the cooperation with the Interstate Commerce Commission, and with other regulative and inspection services, notably the wireless service, the regulation of navigation, municipal gas regulation, standardization of specifications for materials, and central-station power service. The regulation of public utilities is distinctly a measured regulation of their technical details and is efficient only as it is based upon measures and standards. Public-utility regulation simply applies measurements and standards to new fields. Such regulation is effected by the specification of measurable standards for each element so selected as to assure efficient service; these factors may be, for example, the measure of value, quantity, size, composition, quality, speed, and the like. Safety even involves measures where, for example, safety depends upon the strength of the properties of materials or upon safe speed limits.

Such work is an extension of the general purpose of the Bureau as a whole, cooperation in all movements which have for their object increase in efficiency in all fields through measurements and standards. The three hundred or more publications of the Bureau will give a fuller account of the researches and methods by which its work is accomplished.

ELECTRICITY.

The completion of the new electrical building now makes it possible to develop several important new lines of work. As the testing has increased it has been necessary to reduce the time spent in scientific research. In the study and testing of electrical measuring instruments greater accuracy in commercial practice is called for than formerly. As large electric power plants are being established and electric energy sold in greater quantity, and as improvements are made in instruments and methods employed in commercial practice, the necessity for the standardizing laboratory to carry on continual research work is emphasized. An important magnetic research has been under way, viz, the study of the relation between the magnetic and mechanical properties of iron and steel. An important subject to be studied by the Bureau is illuminating engineering and the problems connected with it. The photometric laboratory has been engaged chiefly in testing of lamps and standards for photometric work. A large increase in the work in illuminating engineering would be of great value both to the Government and the public.

In wireless telegraphy the Bureau ought to maintain a first-class laboratory, devoted to the determination of the fundamental facts needed by the various departments of the Government making use of wireless telegraphy. With the present limited equipment and personnel engaged in this work the Bureau has been assisting the Bureau of Navigation and, to some extent, other bureaus of the Government making use of wireless telegraphy.

ELECTROLYSIS.

An investigation was completed on the damaging effects of earth currents upon gas and water pipes, cable sheaths, reinforced concrete, and other underground structures. The results of these investigations are being published, and the Bureau is now in a position to make practical use of the results of these investigations. In such cities as St. Louis, Chicago, Philadelphia, and other large as well as many smaller places where the overhead trolley is used in the street railway system, this problem of electrolysis is a very serious one, and the Bureau is in a position to render valuable service in solving local problems.

GAS INVESTIGATION.

The Bureau's investigation on the testing of gas and the regulation of gas service has yielded very valuable results. A thorough revision of the Bureau's publication on this subject is nearly completed. This work is of very highest importance to cities that regulate the gas service for themselves, and to State commissions, as well as to the gas industry.

PUBLIC-SERVICE COMMISSION WORK.

In many branches of public-service commission work, including electric light and power, street and interurban electric railway service, and telephone service, the Bureau has been of great assistance. Its facilities and personnel should be increased to enable it to study

these problems adequately, in view of the great demand for such advice.

The scientific work of recent years has placed the electrical work of the Bureau on a firm basis, and it is now desirable to develop the engineering side of the work on a scale commensurate with its importance, while at the same time the scientific investigations are continued and developed.

ELECTRIC MEASURING INSTRUMENTS.

The demand for the testing of electric instruments grew steadily during the year. A number of new types of instruments and meters were submitted by the makers for special test. In connection with the testing of electric fans for the Government much progress was made in improving the methods of measuring air delivery. The comparative test of American direct-current watthour meters was completed and the results prepared for publication. New methods of voltage control were worked out for use in the equipment of the new electrical laboratory of the Bureau.

TESTING STANDARD ELECTRIC RESISTANCES.

The testing of standard electric resistances, standard cells, and precision resistance apparatus has proceeded steadily. The investigation on the mercury ohm, the fundamental standard of electric resistance, and an investigation of moving coil galvanometers were nearly completed during the year.

The investigation on the silver voltameter for the standard determination of the unit of electric current has been continued. The third paper of the series giving the results of this important investigation is now in press.

MAGNETISM.

The Bureau's work in magnetism included cooperative work with various organizations along the lines of magnetic testing.

The usual tests have been determinations of total core losses of sheet steel, normal induction of rods and sheet steel, and hysteresis constants of permanent magnet steel. These assist the electrical industry to use the most efficient materials in their manufacture of electrical instruments and machinery. These tests require certain standard sizes of test specimens and involved only standard data for which apparatus had previously been developed at the Bureau and found thoroughly reliable. Other tests have been made for which special apparatus had to be developed or unusual conditions involved greater difficulties. These special tests involved specimens of irregular form, tests of the magnetic properties of the so-called nonmagnetic substances, measurements of temperature coefficients of permanent magnets, and the adjustment and calibration of commercial magnetic instruments not previously investigated.

Investigations have been in progress throughout the year to increase the accuracy of the standard magnetic tests and to broaden their scope. This involved a careful study of existing instruments and the development of new apparatus.

The investigation of the relation between the magnetic, electric, and mechanical properties of steel has been continued. In this the Bureau had the cooperation of the Pennsylvania Railroad in supplying materials and technical assistance. This research gives promise of a new magnetic test which will clearly indicate the mechanical properties, and has already yielded results of practical importance. Preliminary reports on the program of this work have been made before the International and the American Society for Testing Materials.

Cooperation in the development of specifications for standard magnetic tests of iron and steel has been continued with the American Society for Testing Materials through its committee on magnetic testing. A number of industrial institutions have cooperated in several investigations by furnishing material, apparatus, and data.

PHOTOMETRY.

During the past year a complete recalibration was made of all working standards of light intensity. Special attention was given to the carbon-lamp standards used in the pentane standard lamps, since the values for pentane lamps as based upon them by the Bureau differ slightly from the values assigned to the same lamps in England. The mean value for these carbon standards as determined by different groups of observers at different times during the last three years has been the same to within one-fourth of 1 per cent.

To clear up the slight difference from English values a number of carbon lamps, standardized at a voltage which would give the color of the pentane flame, are being prepared to be sent abroad for comparison with the pentane standards in the English laboratory.

In the last annual report, reference was made to an agreement of the Bureau with the National Physical Laboratory of England to interchange a number of tungsten lamps standardized at an efficiency of about $1\frac{1}{2}$ watts per candle in order to establish the international unit in terms of whiter light than it had been previous to that time. Accordingly, the Bureau standardized a group of 30 lamps and the English laboratory sent over a group of 14 lamps. Seven lamps of each group were then sent back to England for measurement. From the results of this intercomparison thus far obtained it appears that within the limit of errors of measurement the units of the two countries, as interpreted through the medium of high efficiency lamps, are in agreement.

During the year there were standardized for the general public and the Government departments and State institutions 71 carbon, 8 metallized carbon, and 314 tungsten lamps, or a total of 393 lamps. Standardization of lamps was undertaken for use by the Baltimore & Ohio Railroad and the Post Office Department, with whom the Bureau cooperated in an investigation of postal-car lighting.

In commercial lamp testing 1,283,000 lamps were inspected for the various Government departments. Of these 651,000 were carbons and metallized carbons, while 632,000 were tungstens. During the previous year (1911-12) 1,221,000 lamps were inspected; of these 847,000 were carbons and metallized carbons and 374,000 were tungstens. The proportion of tungstens increased from about one-third to one-half of the total. The total number of lamps life tested

during the past year was 4,889, of which about one-half were tungstens. During the previous year (1911-12) 4,180 were life tested, of which one-fourth were tungsten lamps.

The work on flame standards has been devoted almost entirely upon pentane lamps. A large number of these continue to be wanted for gas testing in various cities. The Bureau's work has been the standardizing of lamps for this purpose, and experimental tests with a view to prescribing the best methods of operating the lamps. The observations made during the past two years confirm exactly the corrections previously determined at the Bureau for the effect of atmospheric moisture on these lamps. New apparatus has been designed to facilitate routine tests, and to determine more exactly the effects of barometric pressure on the pentane lamp and on other flames. A comparison of various types of standard gas burners to determine which should be recommended for gas testing is desirable, and a beginning has been made in this work.

Besides ordinary tests of portable photometers the Bureau has calibrated a special photometer for the Weather Bureau, making necessary modifications to adapt the instrument for the measurement of daylight of all intensities up to direct sunlight.

A double-mirror selector for the measurement of the distribution of light about lamps and reflectors has been designed and built. A large number of such measurements were made in connection with the investigation of postal-car lighting carried out by the Baltimore & Ohio Railroad and the Post Office Department, referred to above. A number of reflectors were tested also for the Navy Department, which has used the results in its specifications and will hereafter send samples of reflectors purchased by that department, to be tested at this Bureau.

Some attention has been given to street lighting and railroad headlights and signals. During the year the Bureau made a number of tests (both in the laboratory and on the street) of the gas lamps used in Washington. Assistance was also furnished for tests in Philadelphia. The work of the year on headlights and signals has included tests of the candlepower of electric arcs for headlights, and of the transmission of a set of standard signal glasses, and the preparation of a report on proposed headlight legislation, this report being based largely on the experimental work of previous years.

WEIGHTS AND MEASURES.

This year offered the first opportunity for a systematic study of the gold-plated working standards in five years, and the results indicate that the more important standards upon which the work of the Bureau is based did not suffer any change greater than one part in ten million. An investigation of the effect of use and the corrosion of nickel steel and monel metal weights showed that weights made of these materials are far superior in constancy and appearance to plated or lacquered brass weights: the use of these materials is recommended for sealers and others where constancy under continued handling is desired. The routine testing of length, mass, and volume has been carried on in a satisfactory manner. Several investigations or improvements in the methods of testing do, however, merit notice. The cement sieve investigation, begun last year, was

completed, and yielded satisfactory results. During the year an opportunity was offered to make a careful calibration of the mass weight standards of the Bureau.

EXPANSION OF MATERIALS.

The equipment for the determination of the expansion of materials from room temperature to 700°C . ($1,260^{\circ}\text{F}$.) was completed during the year, and the expansion of a number of specimens of steel and nickel-steel alloys were determined. This equipment will be supplemented by apparatus for determining expansion from the temperature of liquid air up to about 300°C . The plans for this apparatus have been completed and considerable work has already been done in the shop, so that there is every prospect that the Bureau will secure during the present year facilities for determining expansion from the temperature of liquid air to 700°C . The apparatus for the determination of expansion at high temperatures has been described, and will shortly be published in the Bulletin.

CEMENT SIEVE TESTING.

The cement sieves are used in the testing of cement to determine the fineness of grain. The necessity for accurate sieves is apparent when it is considered that the most valuable part of Portland cement is that which passes a 200-mesh sieve, and that all Portland cement purchased for the construction work of the United States Government must meet the requirement that 92 per cent shall pass a 100-mesh sieve, and 75 per cent shall pass a 200-mesh sieve. Entirely new methods for testing sieves have been devised which greatly facilitate the work, and also greatly reduce the probability of errors. The manufacturers of such sieves availed themselves of the results of this work and in consequence they are now making a much better grade of sieves.

ANEROID BAROMETERS.

Satisfactory progress was made in the investigation of aneroid barometers, and a report embodying the results of the study of instruments of practically every make and style on the market will be published during the coming year. A knowledge of the action of aneroid barometers which are oftentimes the only means available for determining elevations is of great importance at this time on account of the activity of the army and navy, as well as the public, in the field of aviation. Correct instruments of this type are also required by the various Government surveys, and by Army engineers.

COOPERATIVE WORK WITH STATES AND INSPECTION OF COMMERCIAL WEIGHTS AND MEASURES.

A number of States introduced weights and measures legislation designed to create inspection systems of the weights and measures in commercial use or to amplify and amend laws already on the statute books. In a number of cases these bills were referred to this

Bureau for criticism and necessary amendments. Among States assisted in this way are the following: California, Illinois, Indiana, Iowa, Kansas, Michigan, New Hampshire, Pennsylvania, and Texas. All of these bills received careful attention, many of the sections being revised and some being completely rewritten, with the idea of securing the best legislation possible and of conserving uniformity in the provisions of the statutes of the various States.

As the best means of securing these ends the model law formerly framed by this Bureau and adopted by the Sixth Annual Conference on the Weights and Measures of the United States was followed insofar as local conditions would permit. A number of these suggestions were accepted and several of the rewritten bills were afterwards enacted into law. During the year the model law was carefully revised and eight new sections were added thereto. It was also presented in two new forms to meet the requirements of all classes of States. These amended copies were presented to the Eighth Annual Conference on the Weights and Measures of the United States and were adopted by that body and recommended for passage in those States not yet having a satisfactory code of laws.

PARCEL-POST SCALES.

In October the Post Office Department let contracts for 30,200 scales for use in the Parcel-Post Service, then about to be established. At the request of that department the Bureau assisted in the preparation of specifications, tolerances, etc., and examined and criticized the various models submitted. Afterwards test of the individual scales was made by representatives of the Bureau at the factories of the various manufacturers. The results of these tests were conclusive proof of the necessity of the inspections and resulted in greatly improving the character of the product and in preventing the delivery of many thousand seriously faulty scales.

When it was decided to purchase 50,000 additional scales the Bureau again assisted the Post Office Department in the same way. The inspection of the first two orders, consisting of 25,500 scales, has been nearly completed and once again our inspectors have rejected many thousand incorrect scales and have thus greatly improved the character and accuracy of the product. The study of the variations of spring scales resultant on temperature changes was continued by conducting tests on various types of compensating devices submitted by manufacturers and by investigating the efficacy of various combinations of metals which might be used in these devices.

TOLERANCES AND SPECIFICATIONS FOR COMMERCIAL WEIGHTS AND MEASURES.

The Bureau was represented upon a committee on specifications and tolerances for weights and measures appointed by the conference on weights and measures, and the report of the committee which was accepted by the eighth conference will be used as the basis for specifications and tolerances to be published by the Bureau. Copies of the report of the committee have been sent to practically every manufacturer of such apparatus with the request that they give the Bureau the benefit of any criticisms they may desire to make. Un-

fortunately the demands from the States for such specifications and tolerances has been so urgent that a number of the States have not been able to wait for the criticisms, and the mature consideration of the matter by the Bureau. It is, however, believed that the specifications and tolerances as accepted by the conference were a decided advance, and that no serious mistake has been made by their premature adoption by the States. In fact, there is some advantage in giving them a trial before their final adoption by the Bureau.

WEIGHTS AND MEASURES CONFERENCE.

The Eighth Annual Conference on Weights and Measures was held at the Bureau in May of the present year, and in point of attendance and the character of the program was superior to any heretofore held. Twenty-five States and 29 cities were represented, and also the attendance of a number of railroad-scales inspectors and manufacturers of weighing and measuring apparatus contributed very materially to the success of the meeting. Papers on the following subjects were presented: "Report on legislation during the year;" "The operation of the New York City serialization ordinance;" "Testing of gas meters;" "Testing of water meters;" "Design of scales;" "Experiments on scales and weighing, and technical features of scale action and construction." A full report of the proceedings of the conference will be published during the coming year.

Plans and specifications for the railroad-track scale testing equipment provided for during the year by Congress were sufficiently advanced to enable the Bureau to give the contract for the main part of the equipment to A. H. Emery, Glenbrook, Conn., in March, and at this time the construction of the equipment is well under way. This equipment is radically different from anything heretofore used for testing railroad-track scales. It has been customary for the railroads and others to use a practically solid iron car with a short wheel base, weighing anywhere from 25,000 to 80,000 pounds, as a portable standard weight which could be attached to the rear of trains when transported from one scale to another. The wheels, brakes, etc., of such a car form part of the standard, and consequently any wear and tear upon them affects the test weight.

Where master scales are maintained at intervals on any railroad system on which the weight of the test car can be frequently verified, this is not a serious defect, but where a car might have to be transported from one part of the country to another over several roads, some of which may not have proper facilities for checking the weight of the car, in order to be independent of changes in the running gear caused either by wear or by reason of the fact that a pair of wheels or brakes might have to be replaced, the testing equipment of the Bureau is carried in a specially constructed box car which is provided with an electrically operated crane for handling the equipment. The testing equipment consists of eight 10,000-pound weights, four 2,500-pound weights, and two hundred 50-pound weights, and a truck upon which all or any part of the standard weights may be loaded. The truck will be operated by a worm gear by electric current generated by a 10-kilowatt dynamo driven by a gas engine in the box car.

Auxiliary apparatus will be carried to enable a scientific study of track scales to be made, e. g., upon the flexure of the beams and foundation of the scales under varying loads. In order to place the Bureau in closer touch with the large scales and weighing problems several such scales at important points were visited during the past year. The grain elevators in Baltimore, Md., which are periodically tested under the jurisdiction of the Chamber of Commerce, were also inspected. The factories of several representative scale manufacturers were also visited and details of the construction of large scales were studied. The study of the situation showed the limitations of the common methods of constructing, testing, and maintaining scales, and developed the fact that there was no practice recognized as standard and that local conditions varied greatly according to the character, training, and experience of the men supervising such work. The general information obtained has been used in planning the test weight car equipment to be provided for the Bureau.

The subject matter of the investigation to be conducted with the aid of the test car has been considered and the detailed test to be applied to scales to clear up disputed points and to obtain data for planning the design and construction of scales on a uniform engineering basis has been outlined. Several papers upon the theory and design of scales were prepared for the Eighth Annual Conference on Weights and Measures. In view of these demands, and the inadequacy of the present force to meet them, it is recommended that a special appropriation be asked for the testing of railroad-track scales, elevator scales, and other scales used in weighing test shipments by the Government in its transactions with the public, such as post offices, navy yards, customs scales, etc.

The question of testing railroad-track scales and elevator scales is one that should be taken care of by the Federal Government rather than by the States, for the reason that practically everything weighed upon them is shipped from one State to another, and thus becomes subject to interstate commerce laws. Moreover, it is a matter that has never been taken up except by a few States, and consequently there is afforded a splendid opportunity for the Federal Government to set a standard of inspection for the States to follow. It will be necessary to provide some increase in the equipment and personnel of the weights and measures division during the coming year. The Bureau has been called upon to investigate the scales and methods used in the weighing of various commodities, such as cotton shipments in Texas; corn oil shipments in Louisiana and Chicago; coal and grain shipments in Pennsylvania; grain shipments in New York; belt conveyor at Annapolis, Md.

The Bureau has for a number of years urged the States to establish weights and measures inspection for the protection of the purchasing public, and half of the States are now spending from \$10,000 to \$35,000 each for this purpose. On the other hand, little or nothing is being done by the Federal Government to insure the accuracy of its own scales, although there is ample evidence that some of them at least are among the poorest in use. The Federal Government should set an example in this respect by the establishment of an inspection service which will periodically inspect all Government

scales used in dealing with the public, and should cooperate with the State weights and measures officials in bringing about uniform methods of inspection. The Bureau has already done a vast amount of good in this direction through the National Conference on Weights and Measures, but its value to the States could be greatly increased by keeping in closer touch with the conditions in the States.

In view of the conditions of railroad-track scales disclosed by the investigations of the Interstate Commerce Commission and the Bureau of Standards, and the resulting activity on the part of the railroads in the installation of heavy scales, the recommendations of the Interstate Commerce Commission, which are reasonable enough, provided that they should be performed by this Bureau, and are as follows: That Congress confer authority to fix points at which track scales shall be installed; to prescribe their standard; to test or to supervise the testing, and to supervise the operation of scales. To provide for even the most superficial inspection of railroad and elevator scales, such as is recommended by the Interstate Commerce Commission, several test car equipments will be necessary, and the Bureau should lose no time in supplying the demand for correct railroad and elevator weights.

THERMOMETRY, PYROMETRY, AND HEAT MEASUREMENTS.

THERMOMETRY.

During the past year 791 mercurial thermometers and 13,051 clinical thermometers were tested. These included a large variety of thermometers, e. g., 269 calorimetric and Beckmann thermometers used in determining the heating values of fuels as a basis for large purchases of fuel on specification and in the researches of scientific and technical laboratories; 447 laboratory thermometers ranging from below 0° to 550° C., used for general laboratory and technical purposes; 25 hydrometer thermometers; 41 thermometers designed for special uses; 9 clinical standard thermometers used as standards by manufacturers for the graduation of clinical thermometers; 41 electrical resistance thermometers used for various purposes, e. g., for inspection and investigational work in measuring the temperature of refrigerator cars by one of the Government bureaus, for measuring small temperature changes in calorimetric work of the highest precision, for use as standards in industrial laboratories, for testing thermometers to be used in engineering tests, etc.; and two differential thermocouples for measuring temperature differences in the interval 0° to 40° with an accuracy within a few thousandths of a degree.

Of the clinical thermometers submitted 7.5 per cent were rejected for various causes. These thermometers were submitted by the manufacturers, the several medical bureaus of the Government, hospitals, druggists, physicians, and individual users. Although the total number of clinical thermometers tested represents but a small percentage of the total annual product, experience has shown that it is sufficient to serve as an excellent check on the accuracy of the present day product. This, taken with the practice the Bureau has adopted for some years of sending some of its own standards periodically to manufacturers, has notably improved the accuracy and reliability of the product.

Some progress was made on the investigation of primary standard mercurial thermometers intended for use as standards in the interval 200° to 500° C., including the calibration of their scales and the determination of the effect of temperature on their pressure coefficients. This extension beyond the standard interval from ice to steam point is of special value industrially.

A special electrically heated thermometer comparator was built in the instrument shops for the testing of thermometers in the interval 300° to 600° and has been used with much success when very uniform temperatures are required through a region of considerable volume.

A paper on thermometric lag, with special reference to its effect on precise differential temperature measurements in calorimetry, was published during the year.

As stated in previous reports, a considerable part of the apparatus required for the "porous-plug experiments" has been designed and assembled. This investigation is of fundamental importance in the establishment of the standard scale of temperature and its completion would constitute a notable contribution to the field of thermometric measurements. This investigation has been carried about as far as is possible by a single experimenter.

Progress has been made in the negotiations with the national standardizing laboratories of England, Germany, and France, with a view to international agreement on the standard temperature scales to be used by the several institutions. There is every prospect of a satisfactory agreement.

In some industries having to do with chemical distillations, the character of the various distillates depends on the rate and temperature limits of the distillation. At the request of the chemists of these industries and of members of standardizing committees of chemical societies interested in this work, some experiments were inaugurated with a view to reducing the uncertainty in the temperature measurements as they are ordinarily made in standard forms of distillation flasks and with different types of thermometers.

CALORIMETRY.

During the year 152 standard combustion samples of sugar, naphthalene, and benzoic acid were furnished to chemists and engineers for the standardization of combustion calorimeters used for the determination of the heating values of fuels. The general use of these samples has relieved the Bureau of the necessity of testing great numbers of calorimeters which it would undoubtedly have been called on to test if these samples were not generally available. By the use of these samples the chemist is enabled to check in a few minutes the constants of his entire calorimetric equipment, and the accuracy of his experimental methods, a check which can, therefore, be frequently made and which has done much to reduce all calorimetric or fuel value testing to a uniform basis throughout the country. When this work was begun the Bureau's attention was frequently directed to the settlement of disputes between the buyer and the seller of fuels, arising from the different results of tests made in different laboratories. For example, in one instance involving a large fuel contract, based on the heating value of the coal furnished, the difference in the results of the two tests made in different labo-

ratories amounted to \$25,000 per year in the settlement as made on the basis of one or the other of the tests.

This difference was traced to an error of a few hundredths of 1 degree in the thermometer used in one of the tests. If these standard combustion samples had been available at that time, the party in error would have been able to detect the error by simply burning a weighed amount of the standard sample in his calorimeter and observing whether the resulting heating value differed appreciably from the value given in the Bureau certificate accompanying the standard sample.

The water equivalent of one calorimeter of the bomb type was determined in this section and several gas calorimeters that had been used in important investigations were compared with the Bureau's standardized calorimeters.

Several years ago the Bureau developed a type of electrical resistance thermometer especially adapted to the measurement of the temperature changes met with in calorimetry to an accuracy considerably greater than is attainable with any mercurial thermometer. The results of some improvements in the construction of the above type of thermometer have been described in a paper which is now in press. A considerable demand has arisen for these thermometers, which are now being regularly made by a well-known American instrument maker, in accordance with specifications published by the Bureau. Thermometers of this type, together with the accessory apparatus required in their use, have been installed in numerous industrial laboratories, in scientific laboratories requiring the highest accuracy of measurement, and in some bureaus of the Government. Five of these thermometers were standardized during the year and as many more are now under test.

Considerable progress was made during the year on the investigation of industrial gas calorimeters. It is hoped that the first installment of this investigation can be completed and published in the next few months. The results of this investigation, undertaken at the request of the leading gas engineers, will, it is believed, be of immediate practical importance to gas engineers, inspectors, and public-service commissions, in view of the rapid adoption of heating value standards in place of photometric standards for specifications of quality of gas delivered under contracts and public franchises.

Experimental work has been done on the determination of the capacity for heat of water at different temperatures, and on the temperature coefficient of the specific heat of copper. These investigations are fundamental to the science of measurement of quantities of heat.

Preliminary determinations of the specific heats of milk and of samples of cream for one of the Government bureaus were made in this section.

A special comparator switch was designed and built for the inter-comparison of calorimetric platinum resistance thermometers where an accuracy of a few ten-thousandths of a degree is demanded.

PYROMETRY.

The pyrometric testing included 25 rare metal and 8 base metal thermocouples; 6 pyrometer galvanometers; 11 optical and radiation pyrometers; 2 platinum resistance thermometers; 28 melting points

of fire bricks, furnace slags, and miscellaneous materials; 3 fire-proofing liquids; 3 miscellaneous high-temperature tests; and 191 metallurgical tests, including 5 heating and cooling curves, 63 microphotographs, and 123 heat treatment tests (hardening, annealing, and tempering).

The high-temperature instruments tested were submitted by many different industries in which the control of temperature is an important factor in the quality of product, such as in foundry operations, in the hardening and annealing of steels, in ceramic processes, etc., by technical testing laboratories, and by scientific-research laboratories. Manufacturers of all types of pyrometers are now regularly submitting their standards to the Bureau for test, with the result that one standard scale of temperature is now coming into very general use in the industries, contributing materially to the accuracy of specifications, the reproducibility of product, and the advantageous interchange of experience.

A technologic paper on the melting points of 62 samples of fire brick and of materials of importance in the manufacture of fire brick was published by the Bureau during the year. The experimental work on the melting points of a number of refractory oxides was completed during the year and the results will be published in the near future. This work has shown that some of the hitherto generally accepted melting points of those refractory materials are in error by some hundreds of degrees. Most of the apparatus required for the determination of the thermal conductivity of refractory materials at very high temperatures has been designed, constructed in the Bureau instrument shops, and assembled in the laboratory.

Papers were prepared on "Some characteristics of total radiation pyrometers," "The calibration of optical pyrometers," and "The cold-junction correction for thermocouples."

Much experimental work was done on the monochromatic and total emissivity of iron and nickel and their oxides to furnish data to users of radiation pyrometers, enabling them to reduce observations with these instruments to true temperatures.

A micropycrometer for measuring high temperature melting points (above about 700° C.) was developed during the year and applied to the determination of the melting points of a number of the refractory elements of atomic weight from 48° to 59°. The results will be published in the Bulletin.

Several new furnaces have been designed and installed during the year for special tests and investigations. One of these furnaces has been used in determining the loss in weight of platinum ware when exposed to various high temperatures for various lengths of time, a question of great importance in precise analytical operations carried out in platinum vessels.

OIL TESTING.

Viscosity, flash-point, and fire-point tests were made on 184 samples of oils submitted by various bureaus of the Government. Some work was done on the intercomparison of several makes of viscosimeters widely used in oil testing.

REFRIGERATION CONSTANTS.

In view of the late date of authorization of this investigation and the considerable time required to fill the new positions, experimental work could not be taken up until the year was well advanced. Nevertheless, important progress can be reported at this date. A systematic program of work was planned after consultation with an advisory committee appointed by the American Society of Refrigeration to cooperate with the Bureau. In accordance with this program the first important constant, the determination of which was undertaken, was the latent heat of fusion of ice. This work required a very large amount of special apparatus, which, however, was fortunately at hand, having been developed to meet the requirements of previous calorimetric investigations, so that experimental work could be immediately instituted. At the time of writing the experimental work on this constant has been nearly all completed and it is hoped that the results will be communicated to the forthcoming International Congress on Refrigeration to be held in Chicago in September, 1913. Two quite independent methods of determining the constant were used and the results by the two methods are in most satisfactory agreement.

Other constants of fundamental importance in the field of refrigeration engineering are the physical constants of the liquids and vapors mainly used in refrigeration machinery, viz, anhydrous and aqua ammonia, carbon dioxide, methyl chloride, etc. These constants are the latent heats, specific heats, specific volumes, vapor pressures, densities, etc. A very large part of the special apparatus required for the determination of the latent and specific heats of these liquids has been designed and constructed in the instrument shops and is now being assembled in the laboratories. A special comparator is being constructed to determine the coefficient of expansion of ice. Different methods of preparation of the above liquids are under investigation. A carbon dioxide compressor has been installed to provide means of attaining the low temperatures required in these investigations. All the work has been planned with a view to the determination of each important constant by at least two quite independent methods to insure the highest reliability to the results of the work. Great experimental difficulties are sure to arise in an investigation of this kind, so that it is difficult to fix any date for the completion of such work, but it is expected that important progress will be made during the present year.

The third stage of this investigation relates to the thermal conductivities of insulating and building materials and of types of construction used in refrigeration structures. It was deemed best to defer the inauguration of this work until the work outlined above was further advanced and until an opportunity had been afforded to test the apparatus that has been constructed and methods that have been adopted.

METALLURGY.

The work in metallurgy, which will hereafter be organized as a separate division, has been particularly effective during the past year. All divisions of the Bureau have cooperated in this important

field. The following is a statement of progress at the Bureau in metallurgical and allied investigations and testing during the past year, with a list of recent publications, and an account of work in progress:

A thermal and microscopic study has been made of a series of commercial steels. During this work new and improved apparatus was developed for taking heating and cooling curves of steel in vacuo. The two series of experiments gave results in agreement and have added considerably to our knowledge of the iron-carbon system containing impurities.

A simple method of calibrating optical pyrometers, suitable for works practice, has been devised and a study made of the cold junction correction to thermocouples, which is of importance for works practice.

What is probably the purest iron in existence has been made at the Bureau. A study of the methods of producing this pure iron on a large scale is being undertaken by improved electrolytic methods. This substance will be of inestimable value in making up pure alloys of iron. It has been possible also to make crucibles here for melting this iron without introducing impurities into the metal.

Using samples of nearly pure iron from several sources, a study of the critical ranges (A2 and A3) is being made by the method of heating and cooling curve. This investigation is of great scientific interest, as the question of the allotropy of iron has long puzzled metallographists. It is believed that our sensitive and accurate experiments will go a long way toward settling this elusive problem. The elucidation of the nature, variations, and location of the critical ranges in iron is also of practical metallurgical importance, as the rationale of the heat treatment of iron and steel is dependent on these phenomena. This work for pure iron is practically completed. Whether pure iron, and also steel, possesses critical ranges below 700° C. is again a moot question. A study of this has been begun, using several methods. Several hundred steels are being studied for melting points, emissivities, etc., and may be later examined for other physical properties. These steels are of peculiar interest, in that a great many measurements of electrical, magnetic, and mechanical properties have already been made on some of them by others. Work is also being continued on the melting points of the refractory elements, and it is hoped to determine this constant with exactness for all the refractory chemical elements available.

The Bureau has been greatly aided in this work by the willingness of chemists, from all over the world, to contribute samples of the pure elements they have prepared. Preliminary results have been obtained with Os, Ru, Rh, Ir, Mo, Be, B, Nb, Er, Th, Y, and Zr. Some preliminary work on iron-silicon alloys has been begun with the idea of ascertaining the possibility of reducing silicon from pure silica and alloying the silicon and iron. Also work has been started on an investigation of the variations in apparent carbon content of steels with temperature, size of grain, rate of combustion, purity of oxygen, heat treatment, etc. The preparation of pure carbon-iron alloys has been begun, as well as a study of the wearing qualities of

monel metal and the behavior of enameled apparatus and of a sherardizing plant. There is a wide field here for important work.

A study of the loss in weight of platinum ware when heated is under way for a committee of the American Chemical Society. This has required the construction of a special furnace and satisfactory preliminary results have already been obtained.

An investigation of considerable experimental difficulty and of importance to metallurgical practice is nearing completion on the radiation from metals and oxides. The data obtained will permit giving exact correction to the various optical and radiation pyrometers when sighted on these materials.

Another problem of practical metallurgical importance is the question of rolling temperatures of steel rails. Measurements have been obtained of the practice in four large rail mills, and the results will soon be published with accessory data on the properties of the rails. This work is but preliminary to taking up, if facilities are provided, the vitally important question of the quality of rails.

MISCELLANEOUS.

As in past years an important feature of the work of this division has consisted in furnishing to representatives of many different industries information relating to thermal constants, methods of temperature measurement adapted to the requirements of specific problems, the design of special apparatus to enable large industrial laboratories to do their own routine testing, the Bureau being thus relieved of doing much of this testing, it being only necessary to test the standards of these laboratories. Information was also furnished to a number of laboratories, both industrial and in the Government departments, on specifications for high-grade mercurial thermometers adapted to specific requirements and on complete temperature equipments for scientific work requiring high accuracy. At the request of the Navy Department a member of this division delivered a course of lectures on "Technical thermodynamics" before the post graduate department of the United States Naval Academy. The stenographic notes of these lectures have been printed by the Navy Department for the use of the officers of the fleet.

A member of this division has made a careful study of the "Principle of similarity," a particular view of the theory of dimensions. The study was undertaken, in view of the fact that there appears to be no publications where this principle has been at all completely and clearly set forth and illustrated. This principle is of the utmost importance and utility, especially in experimental hydro and aerodynamics. The advisory committee of the Langley Aerodynamical Laboratory has requested that the part of the paper relating to aerodynamics be submitted for publication by that committee. The complete paper on its completion will be published. A special chapter of the study referred to above relates to an analysis of existing experimental data on the windage of steam turbines, and a paper on this subject will soon be submitted for publication.

OPTICS.

APPLIED OPTICS AND SPECTROSCOPY.

Image-forming instruments.—Image-forming instruments, including telescopes, microscopes, photolens, etc., were tested during the past year in increasing numbers for individuals and corporations throughout the country as well as for the various Government departments. The systems tested range throughout the field of optics from complete examination of the large submarine periscope, which limits the value of the boat as an instrument of war, to the simple measurement of an aperture ratio for the purchaser of photographic lens.

An investigation of discrepancies between the true aperture ratio of photographic lenses and the marked ratio shows that the purchaser does not always get the marked ratio. The cost and selling price of a photographic lens increase rapidly with a slight increase of this ratio.

Improved methods of measuring the residual aberrations have been devised. The measurement of distortion is extremely urgent when the lens is used for photographic surveying, and has to be capable of high precision.

Considerable has been done upon the aberration tolerance of lenses suited to various purposes. Lenses have been constructed for this purpose and other designs are under way. This is a very complex problem but of considerable importance to both manufacturer and purchaser of optical instruments.

This section has been consulted continuously by the Government departments and by all divisions of the Bureau regarding the proper lens systems for specific work.

An investigation of the errors of a set of microscope objectives belonging to this section has been carried out with the idea of having a standard set for rapid comparison with other objectives. Numerous microscope test objects have been collected together but considerable difficulty is experienced in obtaining those suitable for certain objectives. One series of microscope objectives has been found which give greatly increased resolving power by the use of the 436 line of the mercury arc. This is nearly a 20 per cent increase over that attained with ordinary illumination. A new form of eyepiece has been devised which gives promise of increasing the working field of the ordinary well-corrected objective. A circular on photographic lenses is in preparation.

Photographic optics.—In the many uses of photographic equipment there is a demand for increased resolving power and definition. The resolving power depends upon the plate grain and diffusion in the film. An investigation has been made of the plate grain of many plates of the leading American makers. Photomicrographs to a uniform magnification, both of the developed and undeveloped plates, have been made. The effect of developers upon the growth of the image has been studied and an effort made to determine the best methods of working.

Refractometry.—Numerous refractive index determinations have been made for manufacturers and others with the precision spectrometer and also ordinary refractometer determinations.

An investigation is under way to determine suitable refractive index standards for use as a check upon the various refractometers in use by manufacturing concerns and the departments of the Government. The physical characteristic of many hundred compounds have been examined with a view to securing permanent liquid standards of the proper refractive indices. It is too early to predict that liquids will be found which are permanent and suitable, but it is hoped that such will be the case. As stated, hundreds of refractive indices have been measured in this search. This is of great urgency because of the continually growing commercial use of the refractometer as a means of rapidly and accurately detecting impurities in liquids.

Spectrophotometry.—The spectrophotometric tests have been limited during the past year to the necessary routine tests of photographic ray filters, etc., because of the very limited force throughout the greater part of this fiscal year. It is hoped that this work may be continued, especially the investigation upon glass absorption of the invisible ultra-violet radiation and of visible radiation.

The work in spectroscopy has been somewhat delayed through the resignation of the specialist in this subject. The position has now been filled and the work is being reorganized.

The study and planning for an absolute determination of the wave length of neon light was given some attention and deferred so that work in calorimetry could be taken up.

The work which will be done in this section during the coming year is part of a three-year program. This program consists in the measurement, by interference methods, of secondary standards of wave length throughout the entire range of spectrum which can be photographed at present. A few standards will be determined with great accuracy in the ultra-violet, and these will be used in measuring ordinary secondary standards and for other purposes. It is hoped that the inert gases of the atmosphere may furnish excellent standards for this purpose. The greater part of the secondary standards will be measured in the iron spectrum and according to the recommendations of the wave length committee of the International Union for Solar Research.

During the coming year it is hoped that the necessary apparatus for this work will be installed and tests and a beginning made on the measurements. The apparatus under construction, or planned, consists of several etalons and a complete outfit of auxiliary apparatus, a measuring instrument of unique design, a spectrograph of great dispersive power for the ultra-violet, and the mounting for a concave grating. Installations for making plates sensitive to the ultra-violet and infra-red are under way.

The demand for the work of this section is very great and is fundamental to all accurate measurements of light waves, and the physicist, the chemist, the astronomer, and the meteorologist alike require such standards. Furthermore, the wave lengths once standardized may be used in making standards of length.

INTERFEROMETRY.

The chief activity in interferometry has been in the determination of coefficients of expansion of materials. A new method of observation was devised and has been partially tested in practice. A simple formula for change in order of interference due to temperature and pressure changes has been derived and published. New apparatus for temperature control was designed.

In the construction of crystalline quartz apparatus for use in interferometry it became necessary to grind quartz accurately perpendicular to the axis and to test for this adjustment. The methods of construction and testing were studied and the work satisfactorily accomplished. An instrument for testing such quartz plates has been obtained and the Bureau is now prepared to test quartz plates with respect to the orientation of the optical axis.

COLORIMETRY.

Work upon color specification was actively resumed and tentative plans for a spectrum three-color colorimeter were made. An improvised working model was set up and an instrument evolved from this model will be constructed. Attention has also been given to the specification of the color of oleomargarine, and what is hoped to be a practicable method has been outlined and is now being tested. The introduction of bills in Congress and State legislatures aiming to specify a legal limit for the color of oleomargarine has resulted in frequent demands on the Bureau for information and advice on this subject.

The larger part of the recent work has been upon the specification of the color of cottonseed oil. This oil is commercially graded by color, that is, its color fixes the price. Hitherto the methods of testing have been unsatisfactory on account of disputes and contentions between buyer and seller, involving thousands of dollars. The Bureau's work in this field was undertaken in response to an appeal from the chairman of the uniform methods committee of the Society of Cotton Products Analysts. The Bureau has also cooperated in this matter with the chemist's bureau of the New York Stock Exchange. Eleven tests have been applied for and completed. Several hundred Lovibond glasses have been intercompared. Improvements in methods of color testing have been suggested to the cottonseed oil trade and will be adopted. The detailed results of the Bureau's investigation of Lovibond glasses were reported to the annual meeting of the Society of Cotton Products Analysts at Chicago in June, 1913. The improving of these methods will be undertaken by the Bureau in cooperation with that society.

The more urgent needs in colorimetry are a thorough-going experimental study of the trichromatic, monochromatic, and rotary dispersion methods of specifying color; a comparative color study of direct sunlight, diffuse daylight, and some reproducible artificial source (the weather conditions make Washington a quite unsuitable location for studying sunlight and it is desirable that arrangements be made for a period of work at some station of high altitude in a dry climate); a room especially designed for color work and for per-

manent installation of colorimetric apparatus. Its design should provide for light from any direction and any part of the sky as desired, and for a permanently mounted heliostat. It will probably be necessary to provide additional assistance to carry on routine testing in color specification. The repeated demands on the Bureau for advice in specifying standard colors emphasize the urgent necessity of perfecting our equipment and methods as soon as possible.

POLARIMETRY.

To meet the demands made upon the Bureau the work in polarimetry has been more largely heretofore directed upon those problems which closely unite the Bureau and the public. The polariscope and its accessories are the indispensable adjuncts of the refined sugar manufacturer, the beet and the cane sugar planter, the public sugar chemists, and the customs sugar laboratories. In addition, they are part of the regular physical and chemical equipment used in other industries as well as institutions of learning. This polarimetric apparatus is the product of European manufacturers and is not standardized. The working methods used in the laboratories also vary greatly. The necessity for a Bureau publication dealing with these subjects in a comprehensive manner is evident. A unification of methods as well as a common basis of standardization is necessary in order to bring the results obtained into agreement. With the object of accomplishing this the Bureau has prepared a comprehensive circular dealing with these subjects in a thorough manner and touching upon other lines of the Bureau's activities of importance to the sugar industry.

At the New York meeting of the International Committee for Uniform Methods of Sugar Analysis a representative of the Bureau presented a preliminary paper on the basis of standardization of the sugar testing polariscope. A long and careful investigation by the Bureau has shown that the 100° or 100 per cent pure point for sugar has universally been placed at least one-tenth per cent too high. This relatively large error has caused a loss to the revenue from duties collected on imported sugars of over \$500,000 in the last 10 years, the buyer of raw sugar has paid less than he should in the same ratio, and the loss to sugar growers from this source is very large. As a result of the Bureau's work, the International Sugar Commission has appointed a special commission to investigate and make recommendations regarding the matter. The institutions represented on this committee are the Bureau of Standards, the Austrian Sugar Institute, the German Sugar Institute, and the Physikalisch-Technische Reichsanstalt.

An investigation has been made of the values of quartz control plates used by the Bureau as primary standards for saccharimeters. The light source used was the yellow green line ($\lambda=546.1$) of incandescent mercury vapor. The results indicate that previous values were slightly low. The work on the production of monochromatic light of considerable intensity has progressed well.

A large polariscope, designed and built in the Bureau shops, with polarizing and analyzing systems mounted on separate bases, is intended for magneto-optical research in connection with the large electromagnet. A further study of the designs of the perfected sensitive

tripolarizing system, the most sensitive of all polarizing systems, has also been made.

Several researches, of importance from the scientific point of view, and also because of their bearing on the sugar industry, are now nearing completion. Among these are the purification of dextrose, the influence of atmospheric conditions on sugar tests, and a study of the basic acetates of lead. Many samples of dextrose were prepared with a high degree of purity from commercial glucose and from cane sugar. It has been found that atmospheric conditions exert a marked influence upon sugar polarization, and precautions are now available for avoiding this error.

The research on the basic acetates of lead is still in progress. This investigation is intended to apply to the methods of clarifying raw sugar for polariscopic analysis. The research will throw light on the possible compounds which are all grouped under the title of basic lead acetate.

The supervising of the sugar work of the Treasury Department customs laboratories has been continued, and a number of important changes made, including the introduction of the bichromate light filter and improved polariscope tube. The results have been gratifying. The systematic differences existing for years between the tests of the various ports of entry, as shown by the exchange samples, have been gradually reduced. The Treasury Department, in consequence, has had few contests on sugar importations and has won those in which it has engaged.

Many standard samples of sucrose of high purity were prepared and sent out during the year. The research on dextrose has resulted in the preparation of a standard dextrose of high purity. It is expected that the availability of this substance as a standard reducing sugar will have the effect of increasing the analytical accuracy upon which a number of industries depend. The analysis which determines the reducing power of a reducing sugar is somewhat difficult and unreliable if not carefully controlled, but may be made uniformly reliable if the analyst has at hand a standard substance by which he can verify his work. The Bureau is now prepared to issue standard dextrose samples for this purpose.

The amount of testing was considerably larger than in any preceding year. In all about 1,400 tests were made, many of them in duplicate. This does not include the testing of polariscope tubes cover glasses, over 3,100 of which were examined.

The Bureau desires in every way possible to assist in the development of American made scientific instruments. During the year an encouraging beginning was made with polariscopic apparatus. Standard glassware, polariscope tubes, and a bichromate cell, all of improved types, were designed and are being produced by American manufacturers with gratifying results.

RADIOMETRY.

The choice of the problems to be investigated in radiometry is not always determined by their apparent immediate usefulness. For example, the bismuth-silver thermopile, with opaque receiver, which was designed and made by this Bureau, when first proposed, was considered impracticable. It was constructed and several instru-

ments made for the public. Now that its practical utility has been demonstrated instrument makers are adopting its principles. One important instrument maker visited the laboratory and was given practical instruction in the construction of this instrument. From present indications it will displace other forms of radiometers for precision work.

The relations of the radiometric work of this Bureau with the public are useful in other ways than the investigation of radiometers and radiation constants. For example, the Bureau has undertaken to maintain a standard of radiation and to issue simple radiation standards in the form of electric incandescent lamps, calibrated so as to give, in absolute units, the energy radiated from the lamp.

The need of measuring photostimuli radiometrically is growing rapidly among physiologists and psychologists, and considerable time is spent in advising them as to equipment for psychopathic hospitals and physiological purposes in general. The high intensity spectroscope ("illuminator"), designed in this laboratory and mentioned in previous reports, with the radiometric attachment has met with success with these investigators, and is serving as a model for instrument makers. Other advisory work has been done in connection with meteorologists and astronomers engaged in solar radiation work; also beginners in radiation work in various colleges find it convenient to apply for advice and assistance. These are illustrations of the ways in which the Bureau, through its radiation work, keeps in close touch with the public, as affecting particular groups of investigators.

In a broader sense radiometry is useful to the public through the investigation of the constants of radiation of the so-called "black body" (a uniformly heated inclosure). During the past year data on the first part of this investigation were computed and are now in press. These data pertain to the constants of spectral radiation for temperatures to 1,400° C. The results are of the greatest importance in pyrometry and spectroscopy.

A vacuum furnace has been constructed for attaining higher temperatures. Progress has also been made in the construction of apparatus for measuring, in absolute value, the total radiation of a black body, and considerable preliminary work has been done on this subject. Thick quartz plates, ground plane parallel, have been obtained for investigating the capacity of quartz in the infra-red. This is necessary before work can be done on the radiation constants at high temperatures, which requires quartz prisms.

The investigations on "Selective emission of various substances" and "The diffuse reflecting power of various substances," mentioned in previous reports, are now in print. A "Summary of recent investigations of the constants of radiation" (this is a critical analysis of the methods, data, etc.), also minor papers on "Radioilluminator attachments," "Tests of thermopiles," etc., have been published.

The short focus, high intensity quartz lens spectrometer (illuminator) has been remodeled and is now being used in obtaining standard spectral energy curves of incandescent lamps, which have been submitted for test. This apparatus is being used also for determining standard spectral energy curves in the visible spectrum. As a standard source of radiation which is easily procured by the public

the acetylene flame is used. Vacuum tubes filled with helium gas under a standard pressure are also to be investigated.

At the present time the calibration of incandescent lamps, as "radiation standards," is being completed. It is hoped to make some preliminary measurements on the constants of total radiation in absolute value, before there is a change in the temperature conditions within and without the optical pyrometer, and making other preliminary tests, the work on spectral radiation constants, at high temperatures with the vacuum furnace, can not be resumed before fall or winter.

CHEMISTRY.

The routine work in chemistry has shown little change in amount from that of the previous year in spite of a reduction in the number of samples submitted by the general supply committee, and of irons and steels by the Isthmian Canal Commission. These losses have been made up in other materials from the Canal Commission and by an increase of testing for other branches of the Government service. As compared with the previous year the routine work has been handled with somewhat more dispatch, so that complaints on account of delay have been fewer. This improvement has been brought about in part by increasing the efficiency of appliances and the rapidity of a few methods of testing.

Listed by sources, the distribution of routine tests was approximately as follows: Treasury Department, 2,815; War Department, 2,400; Navy Department, 65; Department of Commerce, 482; Post Office Department, 34; United States congressional committees, commissions, and miscellaneous institutions, 373; Government Printing Office, 2,057; State and municipal institutions, 53; private parties, 132; in all, including other departments and parties, 8,446 chemical analyses and tests.

Classified by character of material, the tests were as follows: Irons and steels, 1,170; coated metals, 318; metals and alloys other than iron and steel, 490; cements, 915; asphalt and coal tars, 244; asphalt felts, etc., 109; linseed oil, 270; oil driers, 180; paints and paint materials, 803; varnishes, 367; lubricating oils, 162; rubber, 651; vulcanized fiber, 21; paper, 2,237; inks, printing, 66; sealing wax, 38; flax packing, 34; asbestos, 95; miscellaneous, 61.

ANALYZED SAMPLES.

Early in the year a new material was added to the Bureau's list of analyzed standard samples, namely, sodium oxalate for use in standardizing oxidimetric solutions. Two new acid open-hearth steels with 0.8 and 1.0 per cent carbon were added late in the year. A few renewals were prepared for several exhausted samples. That the demand for these samples is growing is shown by 1,467 samples of irons and steels furnished during the past year, as against 955 furnished during the year preceding, 190 samples of ores as against 136 during the previous year, and 200 of the new sodium oxalate samples. None of the latter were furnished during the previous fiscal year. The net increase amounted to about 50 per cent.

The Bureau is about ready to issue a rolled brass standard sample. The delay is attributable to inability to secure satisfactory agreement among the cooperating analysts. The Bureau will on this account probably restrict cooperation greatly or dispense with such outside analyses altogether in future for materials with which our chemists have acquired sufficient analytical skill, or where experience shows that great delay is to be expected. This course we shall adopt with regret, for experience has shown that cooperation is of great value, both to ourselves and to the participants outside the Bureau.

A date for issuing the cast brass can not be given until a way is found for securing a sample of satisfactory homogeneity. Efforts will be made to solve the problem at the Bureau's Pittsburgh laboratory by experimenting with different conditions of casting, in the hope of receiving a material that will resist oxidation in the operation of mixing.

RESEARCHES COMPLETED.

The results of several researches have been published during the year, certain of these being the results of cooperative work with other divisions of the Bureau, as follows: Atomic Weight of Bromine; The Chemistry of the Filter Paper Voltameter and the Explanation of Striations; Density and Thermal Expansion of Ethyl Alcohol and its Mixtures with Water; Legal Specifications for Illuminating Gas; The Determination of Sulphur in Illuminating Gas; Evaporation Test for Mineral Lubricating and Transformer Oils; The Sampling of Rubber Goods; Preliminary Note on a New Method for Direct Determination of Rubber; Determination of Phosphorus in Steels Containing Vanadium; Note on the Use of Benzoic Acid as a Standard Material; The Constitution of Aluminates.

New editions have been prepared of the circulars relating to the standard samples, which have engaged the attention of several chemists. Tentative methods for the determination of moisture in coal, suggested by the head of the division, were published in a technical journal.

RESEARCHES IN PROGRESS.

Research is in progress upon the aluminium, with special reference to application in the analysis of phosphate rock. The work on lubricating oils now in progress is much hampered by the amount of routine work. It is hoped to secure valuable information in the course of testing deliveries of oil to the Government departments and other offices. Much work has been done on methods of rubber analysis.

The determination of certain physical constants of alcohol has continued and assistance given to the research on refrigeration constants. Cooperative work with the American Society for Testing Materials has included the analysis of a series of pure raw linseed oils of known origin obtained from domestic, South American, and East Indian sources. As a result a specification has been presented to the society for adoption. The Bureau has also conducted similar analyses on 5 types of boiled linseed oil, 11 soya bean oils, and 8

Chinese wood oils to determine their constants so that limits can be specified. It will be necessary to develop special tests to identify these oils, either alone or in mixtures. Analyses will be undertaken on a series of turpentines of known origin to develop standard methods of test and specifications.

An investigation has also been started to develop standard methods of analysis of pigments. A number of commercial white pigments and extenders have been carefully analyzed by several methods, both in this laboratory and in that of the Bureau of Chemistry. The method used in both laboratories show concordant results. The investigation will be continued to include most of the commercial pigments. It is intended to conduct a series of exposure tests on paints for metal protection, since it is only necessary to confirm by several series of exposures the data obtained in previous tests. In an endeavor to devise a more satisfactory method than we now have of determining the quantity of oil and gum present in a varnish some work has been done in determining the normal glycerine content of raw linseed oil and the effect of heating on this quantity.

The investigation to ascertain the changes produced in cement mortars and concrete exposed to sea and alkali waters is being continued. This will include the analysis of a large number of samples of set mortars and concretes which have been exposed to these agencies. An effort will also be made to determine the hydration which occurs in the setting of cement, since it is believed that this determination will afford a measure of the cementing value of the material. The investigation of waterproofing and damp-proofing materials used in building construction will be continued in the endeavor to develop tests to show the value of these materials and aid in formulating specifications.

There are a number of other minor investigations aiming at an increase in the efficiency of the methods of testing now in use which are constantly under consideration.

ENGINEERING INSTRUMENTS.

During the year some 200 water-current meters of various types were calibrated for the United States Geological Survey, the Reclamation Service and other Government departments, and State water supply commissions. An increasing number of private water and power companies and engineering firms are sending their current meters to the Bureau for rating. The construction of a 400-foot testing tank for the rating of current meters has been brought well toward completion and will provide the facilities for much needed investigative work of the characteristics of these important instruments. Sixty-eight steam, vacuum, and air gauges, and special gauges for paper-testing machines were calibrated. Numerous other instruments were tested, including anemometers, tachometers, fire extinguishers, and gas meters. At the request of the Supervising Architect of the Treasury an investigation of the comparative merits of various makes of steam radiator valves has been initiated.

There is an important and increasing demand for more accurate information concerning the fundamental data needed in machine designs and for methods of determining the efficiency of mechanical

devices. This work has been carried on in an exceedingly limited way largely in connection with requests for information on the part of other Government bureaus, but the time has come when it should constitute one of the principal sections of the Bureau's activities.

ENGINEERING, STRUCTURAL, AND MISCELLANEOUS MATERIALS.

The two testing machines of the Emery type, one having a capacity of 2,300,000 pounds and the other 230,000 pounds, are now installed and in operation. The large machine is engaged upon a series of column tests which the Bureau is making in cooperation with the column committee of the American Society of Civil Engineers, and the column committee of the American Railway Engineering Association. This series of tests on columns will take up fundamentally the question of the relation of length in terms of radius of gyration, in which different forms of cross section of component parts of members are used. At the Pittsburgh laboratory, the 10,000,000-pound Olsen machine has been engaged upon work of magnitude which has embraced column tests representing the compression members of the new Municipal Bridge across the Mississippi River at St. Louis.

At Pittsburgh there has also been established a bronze foundry, the work of which is being done in cooperation with a committee of the American Institute of Metals, the work first undertaken being that which pertains to the method of preparation and form of test pieces which shall represent castings under current engineering specifications.

The field work of the Bureau in structural materials has embraced work on the lock gates, lock walls, and emergency dams at the Panama Canal, the physical properties and behavior in place of street pavements, measurement of strains in hulls of ships at sea, continuation of the work on dead load stresses in bridges of large span; and in conjunction with the Interstate Commerce Commission, the continuance of tests on steel rails which are fractured in service and investigative tests on the behavior of the material in locomotive fire box construction.

Several hundred tests were made for various departments of the Government, covering large ropes and cables, concrete specimens from various dams, bronzes and babbitts, cast iron, iron and steel specimens, coke, electric tape, brick, tile, etc., generally to determine their efficiency and suitability for structural service. This work has been done mainly for the Isthmian Canal Commission, Navy and War Departments, United States Bureau of Mines, and the Reclamation Service. A large number of tests have been made for engineering society committees, various firms, and engineers, covering large steel columns, car couplers, concrete columns and floor slabs, street car rails, brick and concrete specimens, pipe, terra cotta, tile, copper plugs, iron and steel samples, turnbuckles, cables, etc., mainly to determine their suitability for service conditions, and also in several cases for a study of physical properties. The laboratory has been placed at the service of the Mine Cave Commission of the State of Pennsylvania and the United States Bureau of Mines to carry on an extensive series of tests covering the efficiency of various aggre-

gates of earth, rock ashes, mine culms, etc., against settlement under great pressures, together with a number of tests of various timber cribs, grillages, props, etc., as to their availability for mine roof supports, earth retainers, etc., which tests have been conducted for several months and are still under way. An elaborate system of strain measurements were made on various sections and lengths of columns to study the effect of initial strains from riveting members, effect of length on crippling load, etc. Two studies were made on large brick piers to determine general deportment under loading to failure.

The function of the structural materials work is twofold—first, in respect to the development of accurate data upon physical properties of materials of construction, and second, upon the practical application of such data in respect to current engineering structures. The laboratory rests pertain to definition of the physical properties of materials in the abstract as the basis and foundation on which engineering constants rest. The varied conditions of service are such that it is not infrequently a matter of judgment, on the part of the engineer, what percentage of the ultimate strength can safely be made use of in structures, and the magnitude of those structures, and the relations which they bear to public safety, are factors which have to be considered. The definition and investigation of those properties which are made use of is one branch of the work of the Bureau and supplementary tests having direct reference to the use of structural materials form a part of the laboratory work; that is, there is a coordination between the laboratory and the users of materials in engineering structures which bring about a special class of testing in the laboratory in addition to the primary ones on the physical properties of material taken in the abstract. The Bureau in this way is brought into direct relationship with the structural engineers and manufacturing engineers of the country and the application of data on properties of material is made direct by the cooperation of the Bureau with the structural engineers of the country.

CEMENTS.

A total of 15,810 samples of cement were tested during the past fiscal year at the Washington, Pittsburgh, and Northampton laboratories, representing in Government purchases about 1,600,000 barrels. The work showed an increase of 15 per cent at Washington, 40 per cent at Pittsburgh, and a decrease of 25 per cent at Northampton, due to a decrease in shipments to the Canal Zone.

Samples of cement to be used in construction of Federal buildings throughout the country and miscellaneous samples received from Government departments and the public were tested at the Washington laboratory; also cements to be used in the construction of docks and inland river improvements.

There were purchased on Government contracts 226,725 barrels of cement at 14 different mills located in Virginia, West Virginia, Maryland, Pennsylvania, New Jersey, New York, and Indiana, which were inspected at the place of manufacture. The inspection included the taking of samples, testing, and subsequent inspection of packing and shipping. This method of inspection is convenient to the pur-

chasing office in that only standard cement is received, and it may be used immediately upon delivery; it is also economical, since fewer samples can be taken, fewer tests made, and shipments can be made immediately on any Government contract from tested stock.

At the Pittsburgh laboratory most of the routine testing was done for the War Department, complete inspection being made at the place of manufacture. The cement for the Isthmian Canal was tested at Northampton. The decrease in shipments to the Canal Zone was caused by the completion of certain phases of the work.

Cement specification.—In an endeavor to obtain a United States standard specification for Portland cement the Government conference of engineers from the various departments, which was successful in formulating a Government standard specification during the preceding year, was reconvened and a joint conference organized composed of representatives from the Government conference, the American Society of Civil Engineers, and the American Society for Testing Materials. While no final agreement has been reached by the joint conference it is anticipated that a uniform specification may be agreed to during the ensuing year.

Investigations upon cement and concrete.—The experimental cement plant of the Bureau has been particularly active during the past year. In all 20 burns were made in the rotary kiln, part of these being of particular interest as bearing upon the effect of magnesia in Portland cement, which has been a much disputed question. The effect of difference of temperature of burns on the same raw material was also studied in the small "stack kiln", and very interesting results obtained. Before they can be considered conclusive they must be duplicated on a larger scale.

There has been conducted in the chemical and microscopical laboratory a great deal of work on the process of hydration of cements, particularly with the use of pure materials. A report of this work is now being prepared. The experimental cement plant has also devoted several weeks to work on clay, marl, and magnesite submitted by commercial interests.

Other investigations were continued or inaugurated during the year, such as a study of sand or silica cements, which is of considerable value to the Reclamation Service, which is now using this instead of Portland cement on some projects. The value of the soundness test and a proposed high-pressure steam test for determining the quality of the cement were investigated. Tests were also continued to determine the effects of heat, moisture, and pressure, separately and combined.

A granulometric analyzer and separator were developed in order to study the value of fine grinding of cements. An investigation was made to determine the sieving value of standard cement sieves. Work was continued on the investigation of volumetric changes which take place in concrete structures, owing to temperature variations and chemical reaction during the hardening of the concrete; this information is necessary in order to properly place expansion and contraction joints to prevent cracking of concrete structures. This work has been done almost entirely in the field, experiments being made on roadways in Michigan, Connecticut, New Jersey, Pennsylvania, and Canada.

In order to determine the effect of alkali waters on cement as actually used in service an advisory committee was organized, composed of representatives from the Reclamation Service, the drainage division of the Department of Agriculture, the Cement Manufacturers Association, and the Bureau. This committee held several meetings and organized a program of tests which included the making of some 8,000 cement drain tile which are to be installed in eight badly alkaline districts in Colorado, Montana, Wyoming, Arizona, Washington, New Mexico, and Utah; also in Missouri and Minnesota for comparative purposes. These drainage tile are to be installed during the late summer of 1913.

An investigation was made to determine the failure of concrete in Bergen Hill Railway tunnel between Hoboken and Jersey City, N. J. This involves both laboratory and field tests which have not been completed.

Some work was done on the investigation of the permeability to water of structural materials, but it had to be temporarily discontinued.

A number of miscellaneous samples of stones, bricks, concrete, and building material were tested for various Government departments.

Steps were taken toward the organization of an advisory committee to outline a comprehensive cooperative program for a field survey and laboratory investigation of the stone resources of the United States. The committee is composed of representatives from the United States Geological Survey, the Bureau of Mines, the Office of Public Roads, and the Bureau of Standards. The work is to be done cooperatively by the various Government offices.

A publication was issued during the year (Technologic Paper No. 12) on the action of salts in alkali waters and sea water on cements.

LIME.

The lime work for the year may be grouped under three general heads: (1) A study of the properties of lime mortar, such as time of set, contraction, crushing, tensile, transverse, and shearing strengths, etc., and also of the properties of cement mortar to which different proportions of lime have been added; (2) attempted solutions of problems in which both makers and users are vitally interested, such as What happens when lime "burns" during the slaking? What is the cause of the popping or pitting of lime plaster? How can the amount of free oxide in hydrated lime be estimated? (3) work in connection with committee C-7 of the American Society for Testing Materials in drawing up specifications for lime. This included the devising of tests to be applied, the testing of different limes, and the comparison of the results with those obtained by other laboratories.

A study of sand-lime brick was completed and a large number of specimens tested and the change in their properties due to weathering was determined.

CLAY PRODUCTS.

The activities of the clay products section during the past year were devoted to cooperative and testing work for various Govern-

ment and State departments, to commercial tests of clays and clay products for the general public, and to investigative work on fundamental problems of a ceramic nature.

Cooperating with the United States Geological Survey 28 samples of clay from the State of Louisiana were thoroughly tested with a view of determining their value in the manufacture of clay products. Cooperating with the Minnesota State Geological Survey 33 samples of clay from Minnesota were tested as to their value in the manufacture of ceramic ware. About 75 tests of clays and clay products were made for the general public. Tests to the number of 35 were made on fire clay, fire brick, paving brick, and molding sands for the Isthmian Canal Commission.

An investigation to establish the limits of the losses of paving brick in the present standard rattler test was undertaken and completed. In this connection samples aggregating 5,000 bricks in number were taken from the streets of 12 cities and tested at this laboratory. The first part of an investigation to determine the value of paving brick and other products made by fusing mixtures of clay and limestone and pouring into molds of the desired shape was completed with promising results.

During the past year the work has been extended into the field of porcelain and white-ware china manufacture, with a view of encouraging in this country the manufacture of porcelain and other pottery products which are now almost exclusively imported into the United States from foreign countries. An investigation of the manufacture of high fire or true porcelain from American materials is now well under way. The manufacture of such high temperature porcelain as thermocouple tubes was studied and the first part of the work completed. The use of leadless or nonpoisonous glazes in the manufacture of American white-ware china is now being investigated. Also an investigation of the electrolytic purification of white burning American clays, with a view of promoting a wider use of domestic clays in American potteries, was undertaken and finished. An investigation as to the effect of time on the vitrification of clays was completed and will be published shortly.

RUBBER AND MISCELLANEOUS MATERIALS.

During the past year the work of the miscellaneous laboratory has been about equally divided between routine tests of miscellaneous materials for Government departments and investigations of the physical properties of rubber. Considerable progress has been made in improving methods of testing and in the development of special apparatus and testing machines.

The miscellaneous materials tested during the year included 816 samples of mechanical rubber goods, such as hose, packing, valves, belting, etc., 34 samples of leather, and 179 samples of rope, wire, metals, etc.; investigations of the life and efficiency of elastic rubber bands, of the aging properties of commercial rubber compounds, and of the properties of leather belting and methods of testing have been continued.

The following investigations have been undertaken during the past year and are now well under way:

1. To determine the relative efficiency of different makes of hack-saw blades.
2. To determine means of identifying "squirted" or machine-made tubes, as distinguished from calendered or sheeted tubes in the case of rubber hose.

The Bureau has continued to receive assistance from manufacturers in the way of rubber compounds for testing purposes, but there is now being installed a complete rubber-mixing and vulcanizing outfit, with the aid of which it will be possible to study the behavior of rubber from the crude to the vulcanized state, and under conditions that may be controlled. This outfit will be of great value in preparing samples of definite composition and different degrees of vulcanization.

As a result of the publication of Circular No. 38, which illustrates and describes the methods used in testing rubber together with the testing machines and apparatus developed at this Bureau, numerous requests for information and assistance are being received. A number of rubber manufacturers and railroad companies are among those who have been furnished with working drawings of the testing machines.

This Bureau is in cooperation with the Navy Department, manufacturers, and technical societies in developing specifications and in perfecting testing machines and methods of testing.

Investigation of the properties of miscellaneous materials should be extended as far as possible with a view to the development of standard specifications for all Government purchasers.

PAPER.

The work in the paper laboratory for the past year includes testing 2,730 samples for the Government service and 80 samples for public and private interests. Much work has also been done on the paper-making equipment, for the purpose of making such additions and improvements as will best serve the purpose desired. A cooperative investigation relative to manufacture and use of casein for the purpose of improving present methods and finished product has been undertaken with the dairy division of the Bureau of Animal Industry, Department of Agriculture. This investigation will have for its special purpose the study of, and improvements in, the utilization of casein for coating and sizing paper.

Cooperation work has been started between this laboratory and all other commercial and Government laboratories now doing paper testing, for the purpose of standardizing methods and to bring about a better understanding for the good of all concerned.

Aside from a general study of improvements in methods of testing paper for Government service, this laboratory has also undertaken work which has for its primary object the securing of information of direct value to the paper industry. The conference between paper manufacturers, commercial testing laboratories, and Government testing laboratory held at this Bureau was of noteworthy interest and did much to establish a better understanding between the manufacturing and Government service. It is proposed to have such a conference each year.

A special investigation has been undertaken, the results of which will be immediately beneficial to lithographers, process printers, and Government map printing. Studies are being made as to cause of and remedies for paper deterioration. A circular relating to paper is being prepared to assist users of paper to more correctly judge a paper for a particular use; this applies more particularly to the smaller users of paper.

Cooperative work has been begun between this laboratory and other laboratories in Government service now doing work relative to the paper industry. This work will save duplication and enable each laboratory to carry on work best suited to its equipment and experience. Cooperative work has also been taken up with the Treasury Department, relative to a more distinctive paper for United States currency.

TEXTILES.

The analysis of imported bagging for cotton for the customs service was an important test. During the year in all 150 individual samples were analyzed. Government departments were advised as to the quality of the goods being delivered upon contract specifications, and as many of the deliveries did not meet the specified requirements a number were rejected upon the results of tests. The textile laboratory rendered valuable assistance to the general supply committee in the drafting of specifications for fabric, carpets, thread, twine, and rope, and the testing of these materials when making awards for the coming fiscal year.

On December 16, 1912, a conference of textile representatives of the various Government departments met at this Bureau. The topics of discussion were the drafting of textile specifications, testing of deliveries, uniformity in methods of testing, and closer cooperation between departments and the Bureau. Five different departments were represented, seven of the delegates being purchasing agents. This conference accomplished much good and was effective in bringing about closer cooperation with the Bureau.

At the request of the National Association of Cotton Manufacturers a paper was prepared, "Humidity effects upon textile material," for their annual convention. During the year Circular No. 41, "Testing and properties of textile material," and Technologic Paper No. 19, "Physical testing of cotton yarns," were prepared. In addition to these there were five technical articles written upon textile topics.

The following investigations were undertaken, and most of them were completed during the year: The number, tensile strength, yards per pound and per spool of the more common brands of spool thread used by garment manufacturers and in the household; methods of ascertaining the wool content of a wool and cotton fabric; the extraction of sizing and loading material in cotton goods; stripping of the dye or color in fabrics, etc.; the "regain" of moisture of cotton yarn and fabric of various common commercial makes; short correct methods for determining the yarn number of yarns, upon cops, bobbins, spools, etc., and the rapid determination of the finest yarns present in a fabric; the "shrinkage" in scouring some excep-

tionally heavy foreign wool fleeces and the percentage moisture and "regain" of raw wool, also the clean (scoured) wool under standard atmospheric conditions; the difference in number, strength, and weight of commercially identical worsted yarns manufactured by different concerns and sold on the market at the same price; the moisture present and the "regain" of moisture of worsted tops, under standard atmospheric conditions; the influence of humidity upon worsted yarns.

It has been only a short time since definite specifications have been employed and these are used to a limited extent by the more progressive concerns. Close cooperation exists between the textile section of this Bureau and the Bureau of Plant Industry, Department of Agriculture, and at the present time the Bureau is helping them in their studies of methods of improving the grades of cotton and the marketing of same.

The Government departments have requested the Bureau to assist in drafting specifications for textiles and to test goods delivered upon contracts.

THE OFFICE.

LIBRARY.

The number of accessioned volumes in the Bureau library is now 10,414; 326 periodicals, 215 of which are by exchange and 111 by subscription, are currently received here and at Pittsburgh. The extra copies of copyrighted books relating to the Bureau's work have been transferred from the Library of Congress to the Bureau, as in previous years.

PUBLICATIONS.

The following new Circulars were issued during the year: "Electric wire and cable terminology," "The physical testing of mechanical rubber goods," "Specifications for and measurement of standard sieves," "Sodium oxalate as a standard in volumetric analysis," and "Testing and properties of textile materials."

The following Scientific Papers were issued: "A new precision calorimeter," "Instruments and methods used in radiometry," "Antenna resistance," "Energy losses in some condensers used in high-frequency circuits," "Selective radiation from various substances," "On a modified form of stability test for smokeless powder and similar materials," "Atomic weight of bromine," "The silver voltameter—Part I, first series of quantitative experiments," "The silver voltameter—Part II, the chemistry of the filter-paper voltameter and the explanation of striations," "The diffuse reflecting power of various substances," "Density and thermal expansion of ethyl alcohol and of its mixtures with water," "A micropyrometer," and "A simplified formula for the change in order of interference due to changes in temperature and pressure of air." Five numbers of the Bulletin were issued.

The following Technologic Papers were issued: "Comparison of five methods used to measure hardness," "Action of the salts in alkali

water and sea water on cements," "The evaporation test for mineral lubricating and transformer oils," "Legal specifications for illuminating gas," "The manufacture of lime," "The function of time in the vitrification of clays," "Physical testing of cotton yarns," "Determination of sulphur in illuminating gas," "The dehydration of clays," "The technical control of the colloidal matter of clays," "The determination of phosphorus in steels containing vanadium," and "The effect of overfiring upon the structure of clays."

PERSONNEL.

During the fiscal year 1913 the personnel consisted of 193 persons employed in statutory positions and about 88 upon special research and investigation specially authorized by Congress. The statutory positions were classified as follows:

Scientific.—One chief physicist, 1 chief chemist, 2 associate chemists, 3 physicists, 12 associate physicists, 32 assistant physicists, 7 assistant chemists, 38 laboratory assistants, 15 aids, 12 laboratory apprentices, and 3 laboratory helpers; total, 126.

Office.—Secretary, 1 storekeeper, 1 librarian, 14 clerks, 1 packer and shipper, 5 messenger boys; total, 23.

Operation of plant.—Superintendent of mechanical plant, 4 assistant engineers, 2 electricians, 3 firemen, 3 watchmen, 1 messenger, 5 skilled laborers, 4 laborers, 3 janitors, 2 female laborers, 1 telephone operator, 1 elevator boy; total, 30.

Construction.—One chief mechanic, 8 mechanics, 2 skilled woodworkers, 1 draftsman, 1 glass blower; total, 13.

SUMMARY OF TESTS.

The work of the Bureau involves, among other things, a large amount of testing of standards, measuring instruments, and materials. A certain amount of this work is already organized on an accurate routine basis and is handled with dispatch, through increased efficiency of appliances and methods of testing. Much of it, however, involves investigation of the scientific principles underlying the test, a study of existing methods, and the development of new standard tests of known accuracy. In such cases the research which must precede the actual testing is a most important function of the Bureau. For the test a reasonable fee is charged, except when made for the National or State Governments. The corresponding amounts for Government testing are of interest, however, and are added to the statement of tests which follows:

NUMBER AND VALUE OF TESTS COMPLETED, FISCAL YEAR ENDED JUNE 30, 1913.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length.....	219	\$1,051.25	481	\$691.75	700	\$1,743.00
Mass.....	1,719	1,365.00	729	382.80	2,448	1,747.80
Capacity.....	4,404	1,650.00	1,322	784.45	5,726	2,434.45
Temperature.....	2,594	1,209.16	10,952	3,373.23	13,546	4,582.39
Hydrometry.....	1,976	2,019.25	152	238.60	2,128	2,257.85
Miscellaneous.....	11	65.00	4	57.00	15	122.00
Optical.....	1,538	1,382.00	393	214.75	1,931	1,596.75
Electrical.....	378	798.75	396	1,740.90	774	2,539.65
Photometry ^a	4,950	15,127.00	310	1,105.50	5,260	16,232.50
Chemical ^b	8,353	55,077.15	1,667	3,251.00	10,020	58,328.15
Physical and mechanical tests:						
Engineering (miscellaneous).....	819	2,152.00	6	10.00	825	2,162.00
Engineering (instruments).....	206	1,081.00	31	150.50	237	1,231.50
Structural materials.....	15,936	25,208.20	255	1,296.00	16,191	26,504.20
Paper and textiles.....	3,444	7,096.33	120	181.00	3,564	7,277.33
Total.....	46,547	115,282.09	16,818	13,477.48	63,365	128,759.57

^a In addition, the Bureau inspected 1,283,289 incandescent lamps at various factories for other departments of the Government, the fees for which would amount to \$11,682.69.

^b 3,834 of these tests, amounting to \$33,913.75, were chemical tests made on structural materials.

The receipts for tests were as follows:

Total receipts, 1913.....	\$13,439.48
Received prior to July 1, 1912, for tests completed in fiscal year 1913.....	\$643.75
Outstanding fees.....	55.65
Refunds.....	20.17
	719.57
	14,159.05
Received for tests completed, fiscal year 1912.....	28.00
Received for tests in progress at close of fiscal year 1913.....	653.57
	681.57
Fees for tests completed, fiscal year 1913.....	13,477.48

FINANCIAL STATEMENT.

The following statement shows the amount and object of each appropriation provided for the Bureau for the fiscal year 1913, the disbursement during the year, the amount of unfilled and unpaid orders at the close of the year, and the unexpended balance remaining at the close of business June 30, 1913:

Appropriation.	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries.....	\$241,312.66	\$216,974.96	\$9,724.66	\$14,613.04
Equipment.....	52,000.00	29,011.21	22,859.30	129.49
General expenses.....	25,000.00	19,435.86	5,413.86	150.28
Grounds.....	3,000.00	2,585.72	409.91	4.37
Testing structural materials.....	77,342.50	70,277.27	6,962.71	102.52
Testing machines.....	30,000.00	25,700.82	4,277.78	21.40
Investigating effects of electric currents.....	10,000.00	9,095.18	813.65	91.17
Refrigeration constants.....	15,000.00	9,580.23	5,415.13	4.64
Water current meter testing tank.....	5,000.00	1,270.00	3,005.80	724.20
Equipment, electrical laboratory.....	25,000.00	2,160.73	20,552.97	2,286.30
Additional land.....	85,000.00	68,034.00	.....	16,966.00
Testing machine (Emery).....	180,000.00	179,866.23	.....	133.77
Testing structural materials of the United States.....	23,350.00	23,350.00	.....	.....
Testing machine at Pittsburgh.....	25,000.00	24,974.95	.....	25.05
Laboratory.....	200,000.00	171,444.76	24,195.02	4,360.22
Total.....	997,005.16	853,761.92	103,630.79	39,612.45

The following statement shows the condition of the appropriations for the two preceding fiscal years at the close of business June 30, 1913:

Appropriation.	1911				1912			
	Total ap- propria- tion.	Disburse- ment.	Lia- bility.	Balance.	Total ap- propria- tion.	Disburse- ment.	Lia- bility.	Balance.
Salaries.....	\$201,440.00	\$189,552.27	.....	\$11,887.73	\$236,340.00	\$224,050.96	.....	\$12,289.04
Equipment.....	46,000.00	45,910.60	\$25.34	64.06	52,027.50	50,570.33	\$1,198.50	258.67
General expenses....	20,042.37	19,960.61	.20	81.56	25,702.77	25,248.74	215.04	238.99
Grounds.....	3,000.00	2,785.57	.....	214.43	3,000.00	2,892.93	.....	107.07
Testing structural materials.....	55,109.10	54,917.81	.....	191.29	78,533.50	77,987.37	315.52	230.61
Investigating effects of electric currents.	15,000.00	14,859.58	38.92	101.50	15,000.00	14,807.11	69.65	123.24
Weights and meas- ures.....	10,000.00	9,081.89	.....	918.11	.....	.....	.....	.....
Testing machines....	.....	.....	.....	.....	30,000.00	29,793.92	.....	206.08
Total.....	350,591.47	337,068.33	64.46	13,458.68	440,603.77	425,351.36	1,798.71	13,453.70

Respectfully,

S. W. STRATTON, *Director.*

To Hon. WILLIAM C. REDFIELD,
Secretary of Commerce.





